SN Ia Reddening

Saurabh W. Jha

SDSS SN Collaboration meeting

Argonne National Lab 2010 October 24

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THE STATE UNIVERSITY OF NEW JERSEY

image from Gendler et al., http://www.eso.org/public/images/eso-m100/

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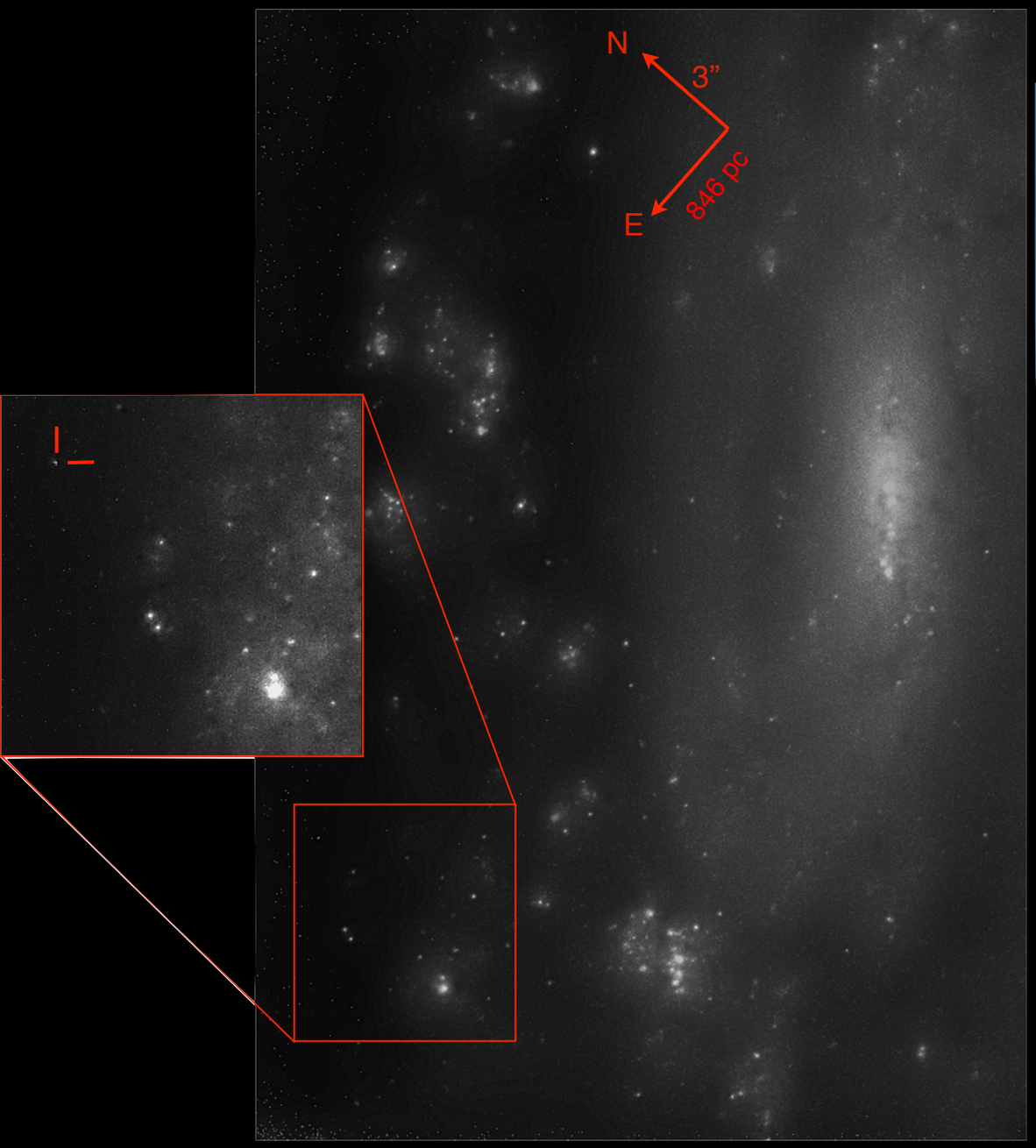
02cx-like SN 2005hk and 2008A



HST imaging of SN 2002cx-like SN 2005hk and 2008A from McCully et al. (in prep.)

Hubble Space Telescope and Ground-Based Observations of SN 2005hk and SN 2008A: Subluminous SN 2002cx-like Type Ia Supernovae

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ABSTRACT

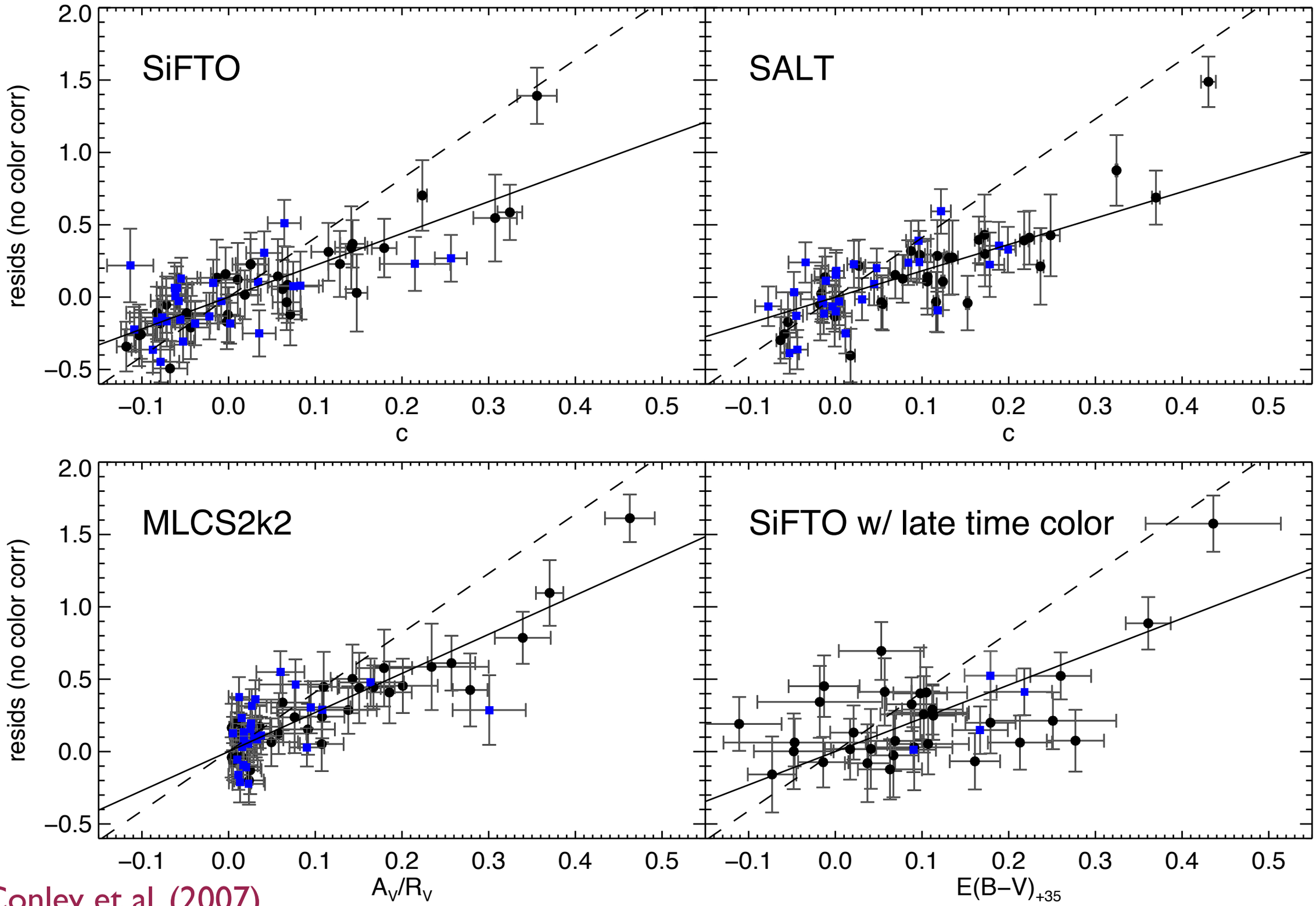
We present Hubble Space Telescope and ground-based optical and near-infrared observations of SN 2005hk and SN 2008A, members of the SN 2002cx-like subclass of peculiar type Ia supernovae (SNe Ia). Though subluminous and with low expansion velocities, these objects look spectroscopically similar to normal SNe Ia at early times, but deviate dramatically at late times, never showing the dominant nebular emission lines that are observed in normal SNe Ia (and indeed, in SNe of all types). Instead the spectra show permitted lines of Fe II, Ca II, and possibly Fe I more than a year past maximum light, along with very narrow [Fe II] and [Ca II] emission. We use these lines to estimate the temperature and density of the ejecta, and find that the density at late times for these objects is still extraordinarily high in the late phases. These high densities should yield enhanced cooling of the eject, making these objects good candidates to observe the "infrared catastrophe", a generic feature of SN Ia models. However, our HST photometry of SN 2008A does not match the predictions of an IR catastrophe. One proposed explanation for these peculiar SNe Ia is a pure deflagration explosion, for which models predict significant unburned oxygen in all layers of the ejecta. We find an upper limit of 0.03 $M_{\odot}$ of oxygen with a density below 10^6 cm^{-3} can exist in SN 2008A $\sim$ 600 days after maximum light, strongly at odds with the pure deflagration prediction. We propose that a failed deflagration explosion could qualitatively be a good model for SN 2002cx-like SNe Ia.

1. Introduction

The use of type Ia supernovae (SNe Ia) as distance indicators has revolutionized cosmology with the discovery that the expansion of the Universe is accelerating, driven by dark energy (Riess et al. 1998; Perlmutter et al. 1999). In general, SNe Ia show homogeneity in their observed properties (see e.g., Filippenko 1997), with quantifiable heterogeneity relating their light curves and spectra with their intrinsic luminosity (Phillips 1993; Nugent et al. 1995). Well-observed SNe Ia can typically yield distances accurate to better than $\sim$ 10% (e.g., Jha et al. 2007) and today are being used to constrain parameters like the Hubble constant, the age of the Universe, and the equation of state of dark energy to high precision (e.g., Riess et al. 2007, 2009). As large samples are collected, systematic uncertainties in our ability to derive SN Ia distances are beginning to dominate the statistical uncertainties (e.g., Wood-Vasey et al. 2007; Kessler et al. 2009; Sullivan et al. 2010).

Perhaps one of the most fundamental systematic uncertainties stems from the lack of detailed

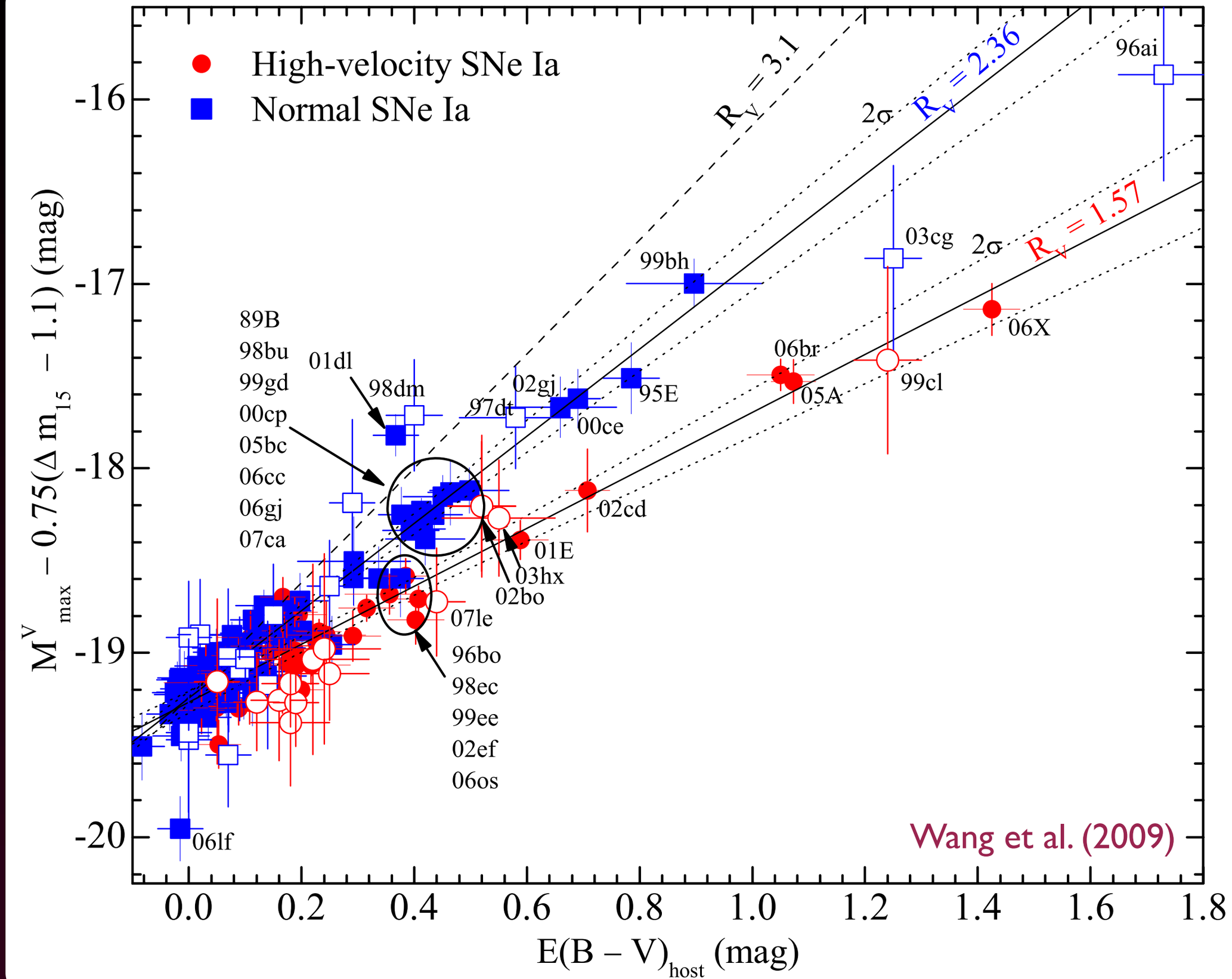
SN Ia luminosity vs. color excess



Conley et al. (2007)

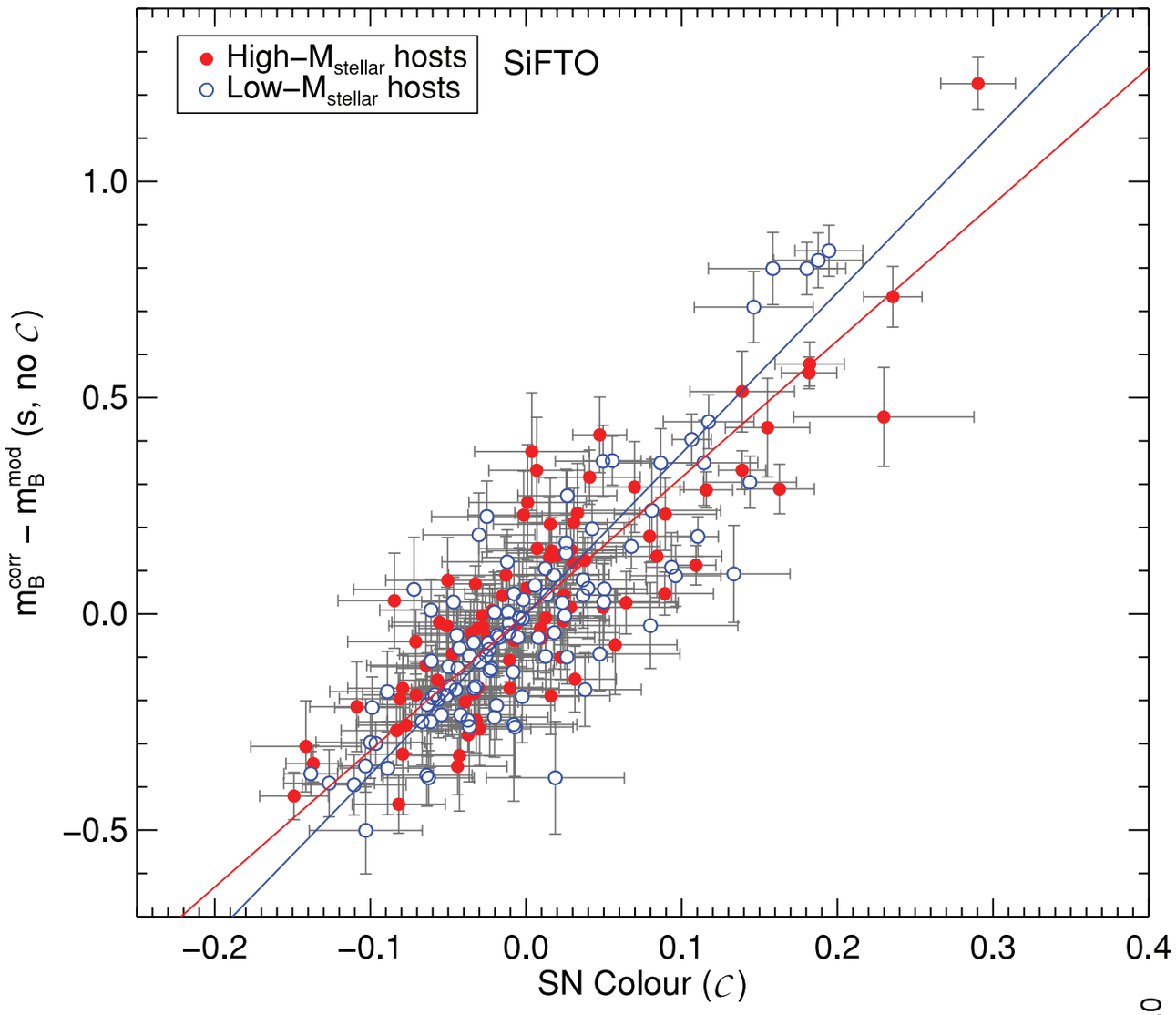
intrinsic color/luminosity relation or "local" dust?

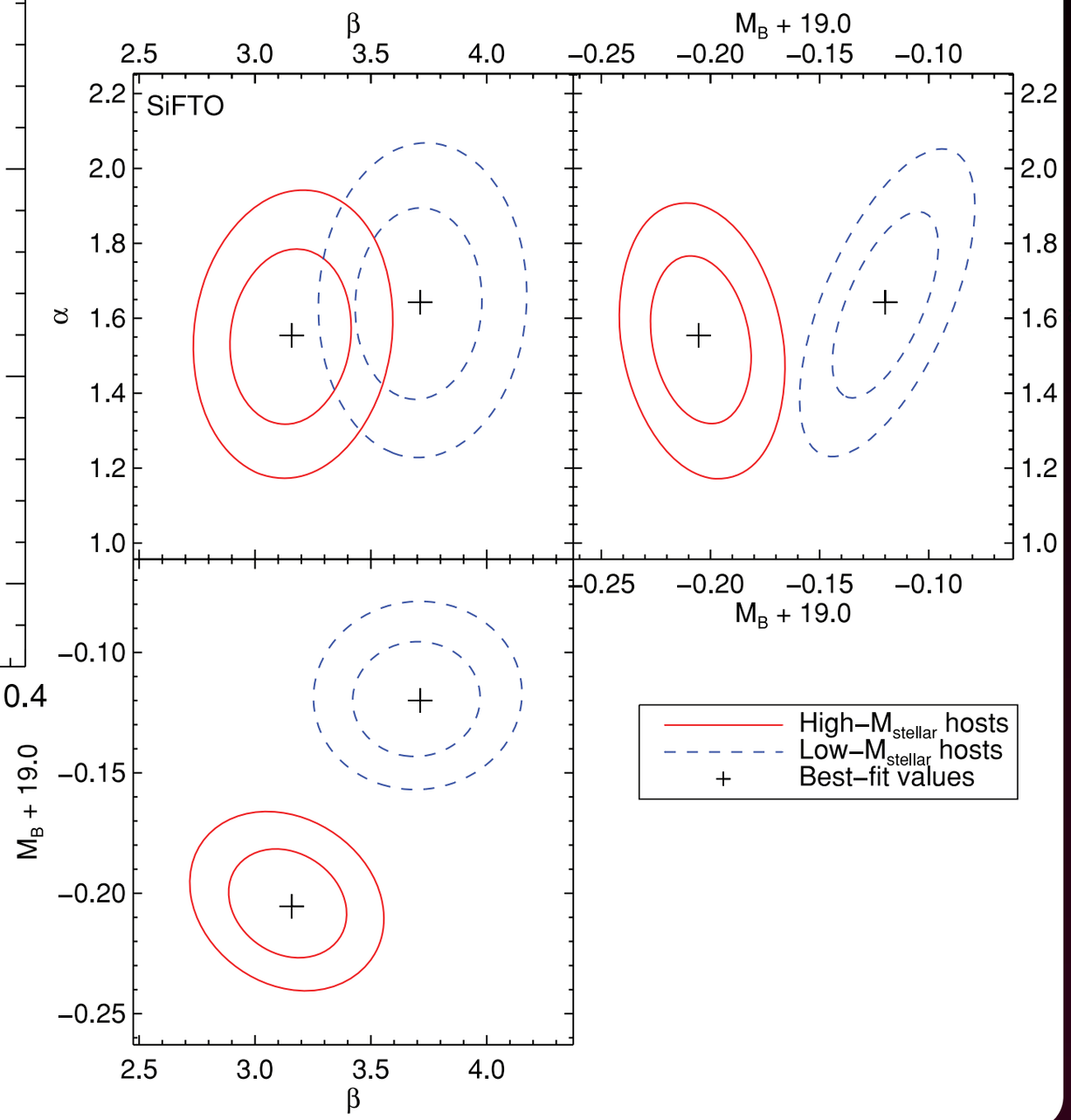
SN Ia reddening: variation by SN velocity



Wang et al. (2009)

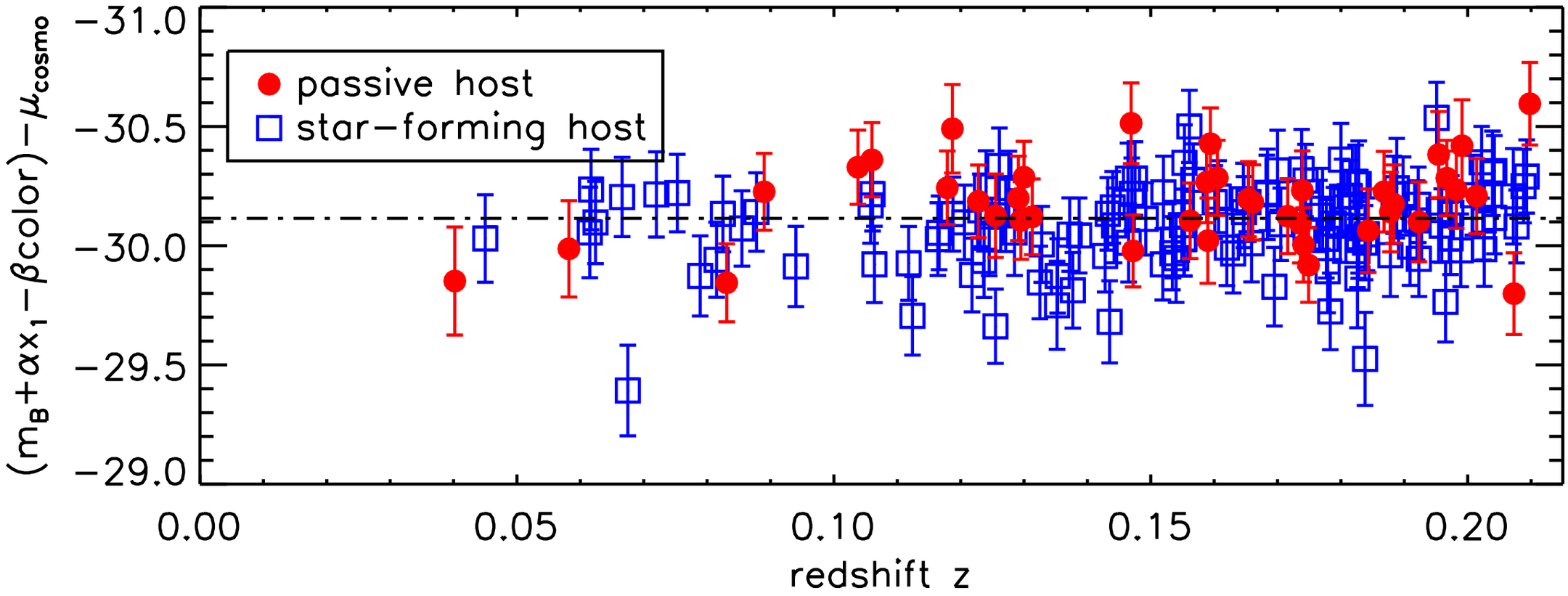
SN Ia reddening: variation by host galaxies





SNLS; Sullivan et al. (2010)

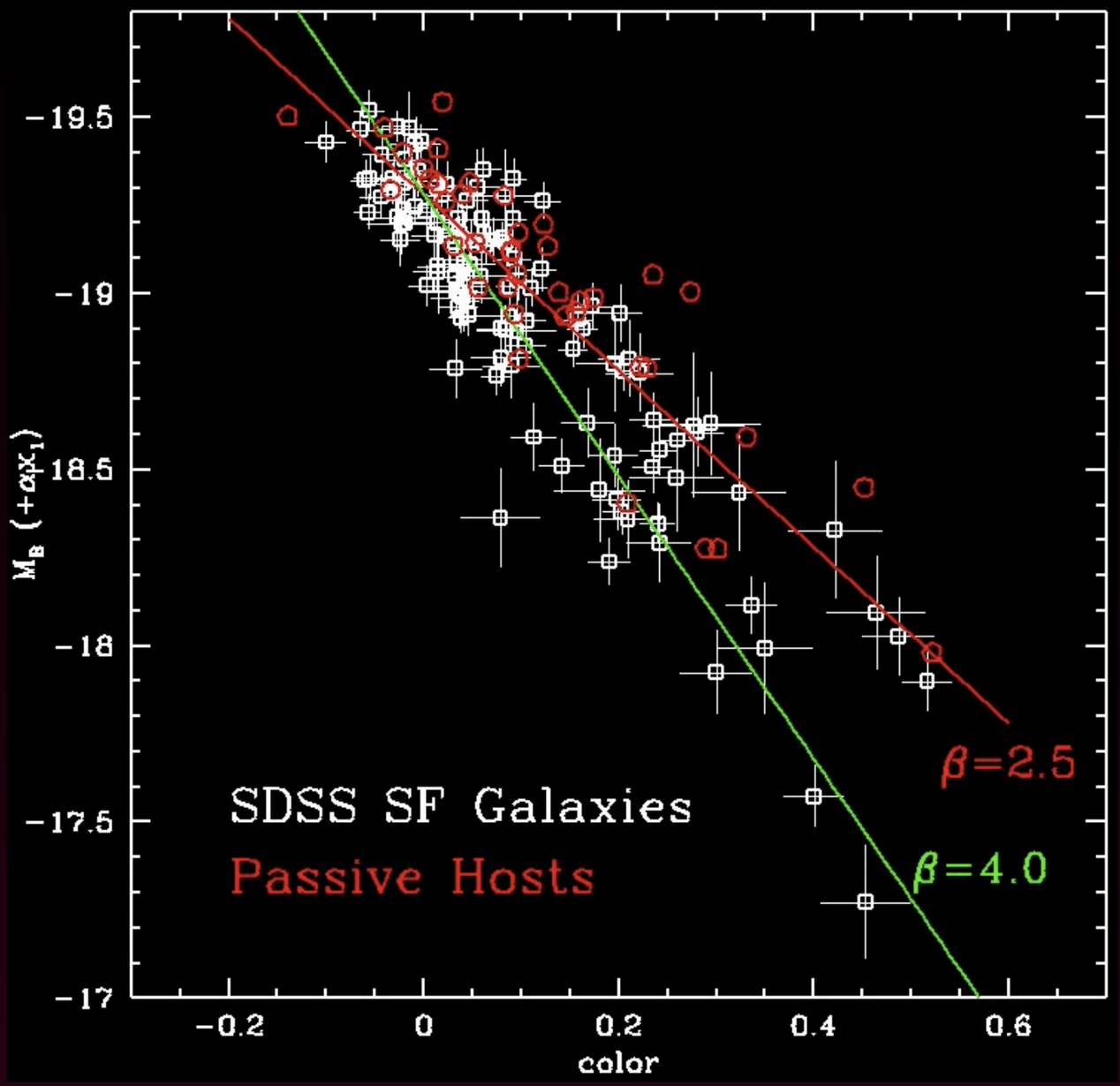
SN Ia reddening: variation by host galaxies



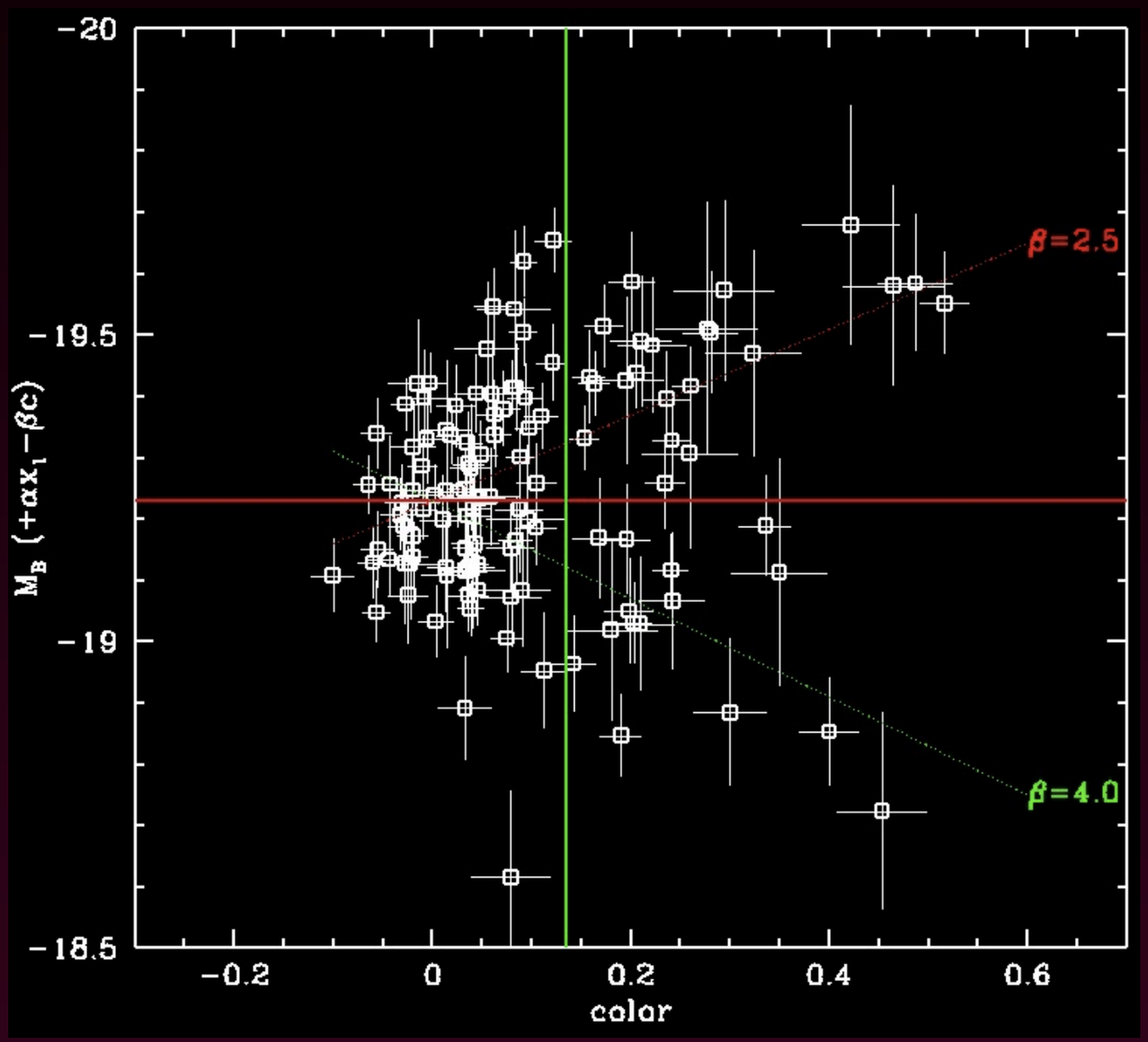
Host Galaxies	Restricted[a]	M	α	β	χ^2	No. of SNe
passive	no	-30.19 ± 0.03	0.16 ± 0.02	2.42 ± 0.16	34.46	40
	yes	-30.23 ± 0.05	0.18 ± 0.03	2.50 ± 0.41	12.60	27
star-forming	no	-30.10 ± 0.01	0.12 ± 0.01	3.09 ± 0.10	143.63	122
	yes	-30.11 ± 0.02	0.16 ± 0.02	3.22 ± 0.20	94.55	89

SDSS SN; Lampeitl et al. (2010); see also Kelly et al. (2010)

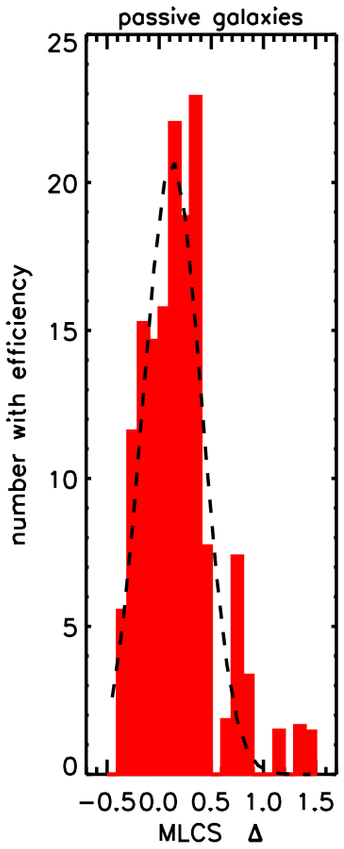
SN Ia reddening: variation by host galaxies

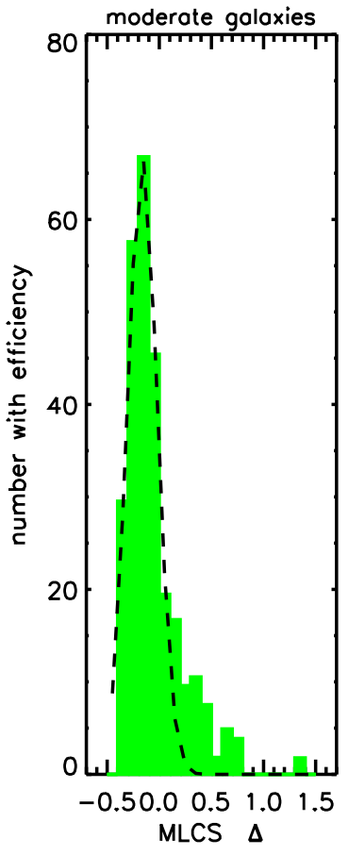


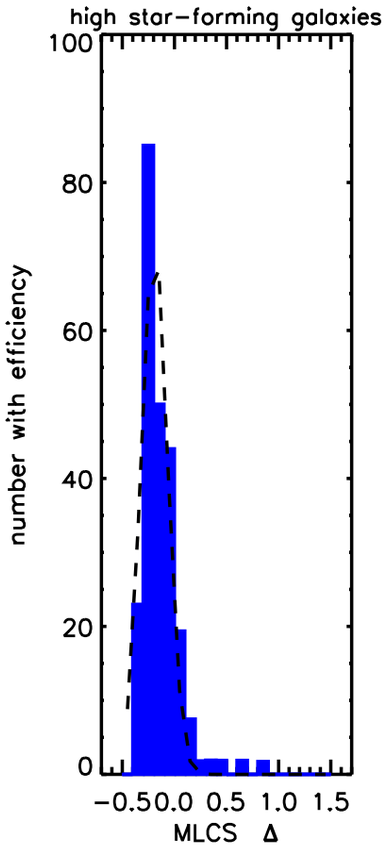
SDSS SN; Lampeitl et al. (2010)
Garnavich et al. (in prep)

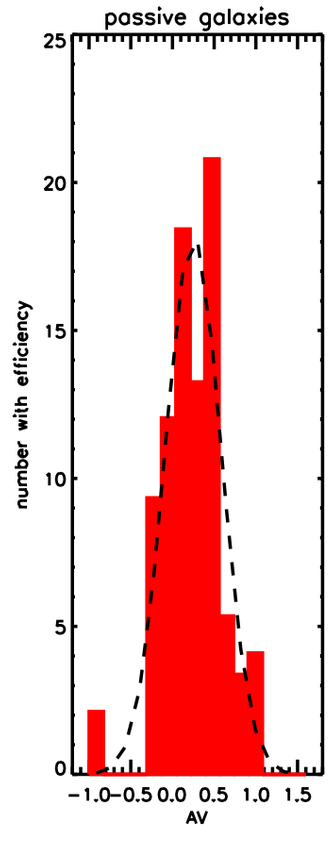


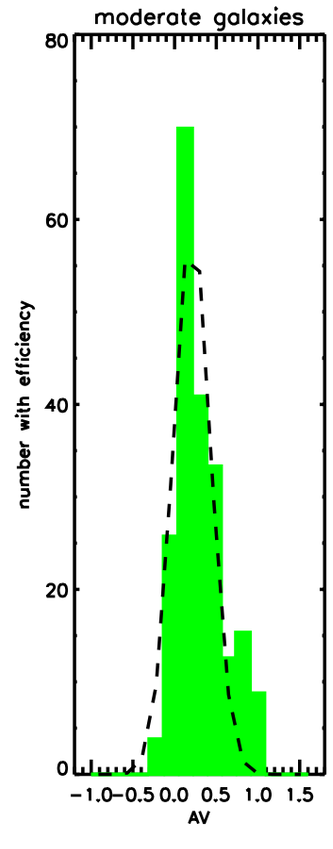
SDSS; Smith et al. (in prep)

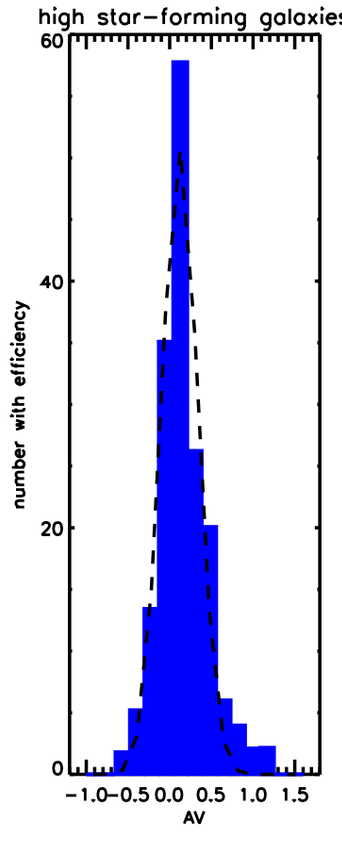


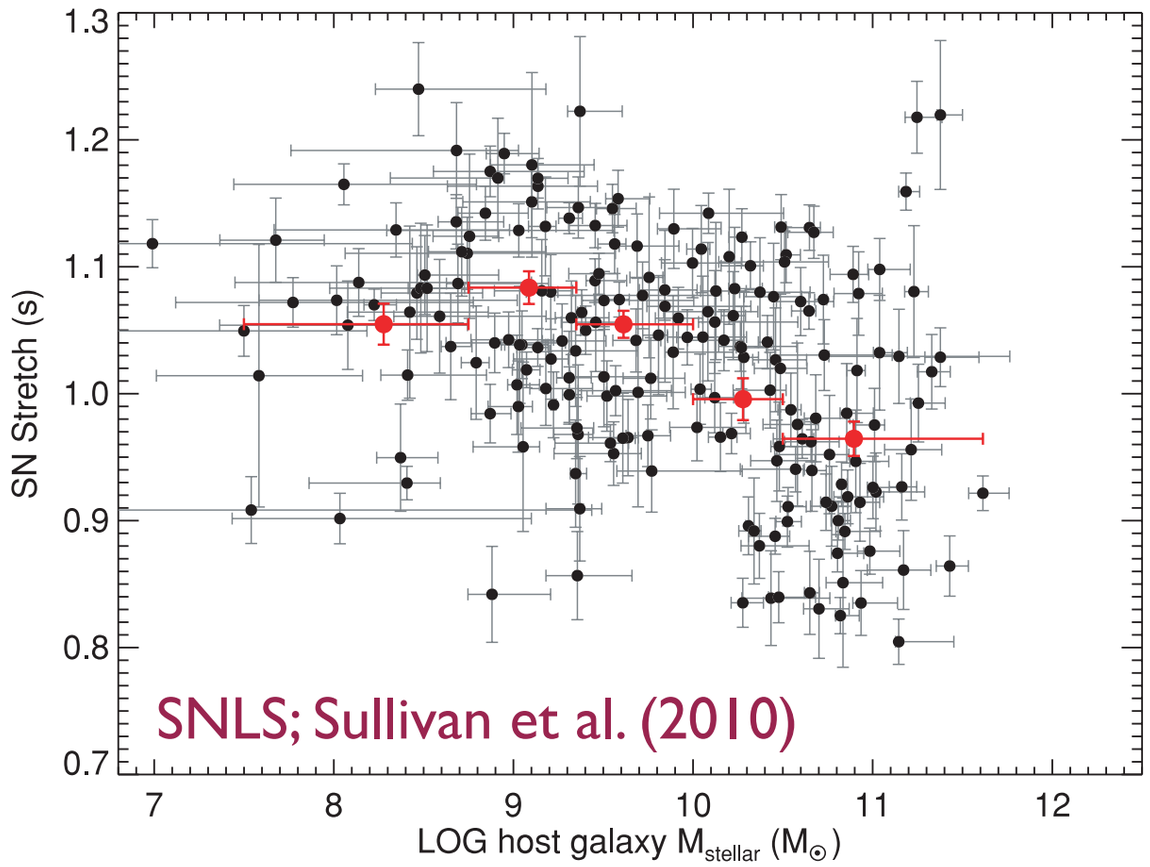




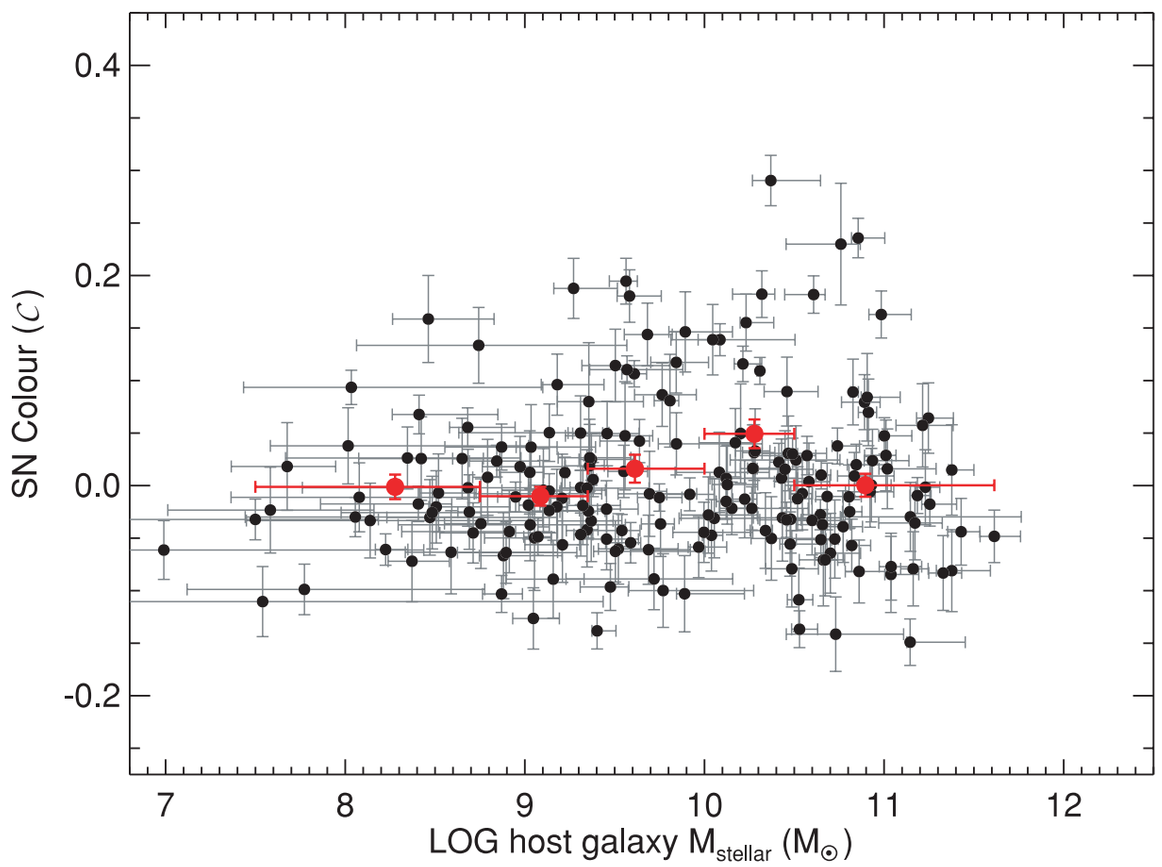




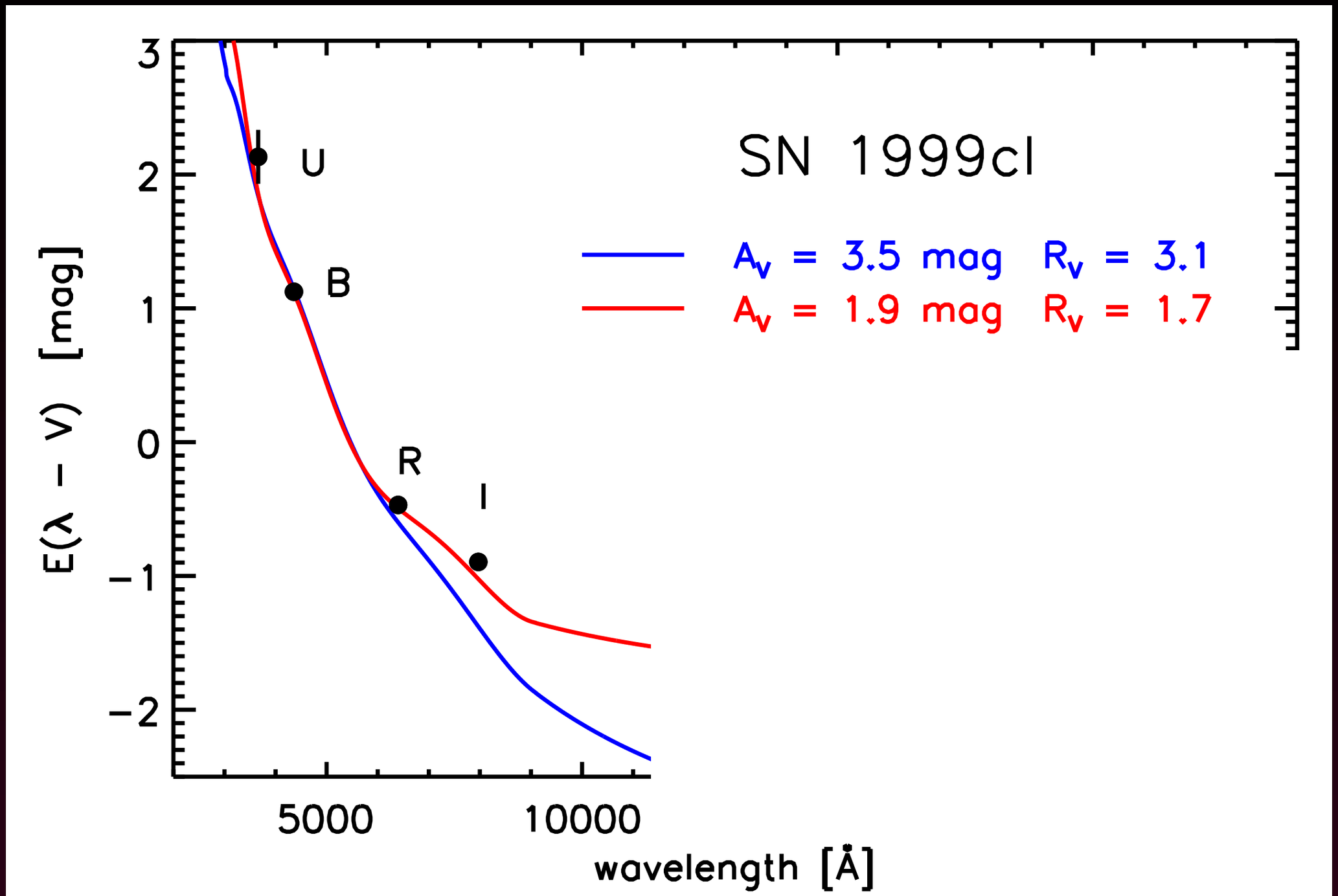




SNLS; Sullivan et al. (2010)



reddening: local(?) host galaxy dust



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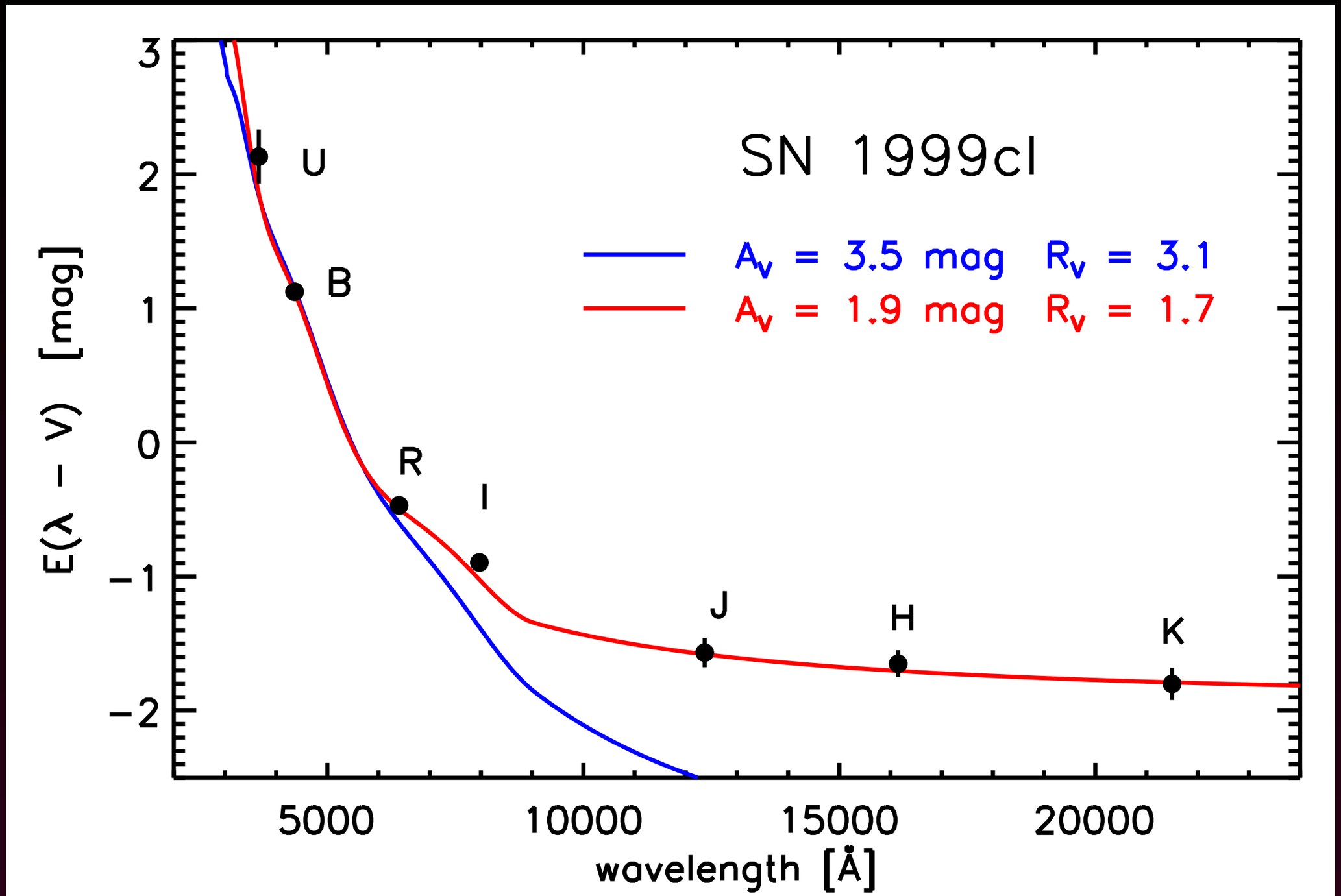
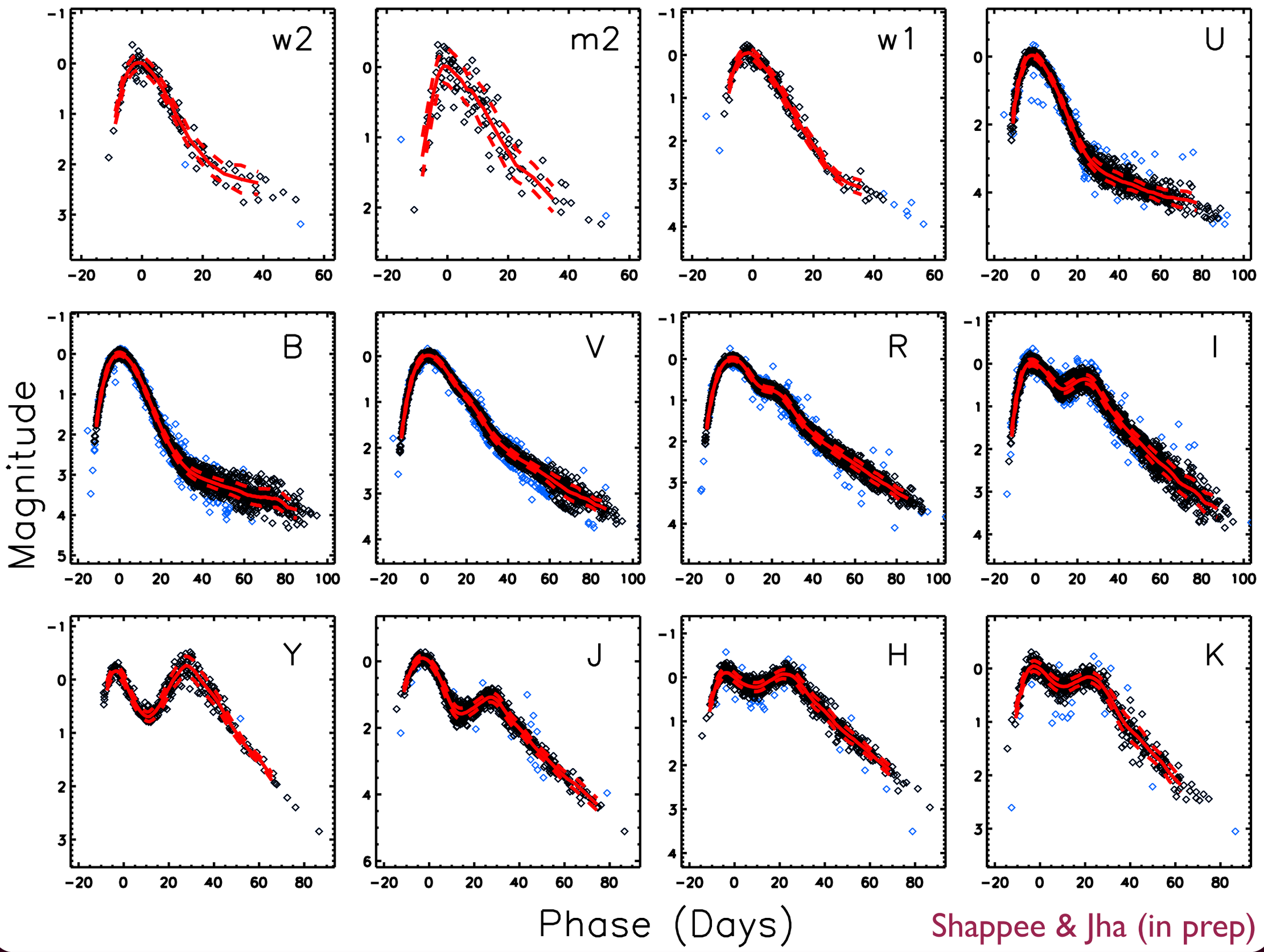


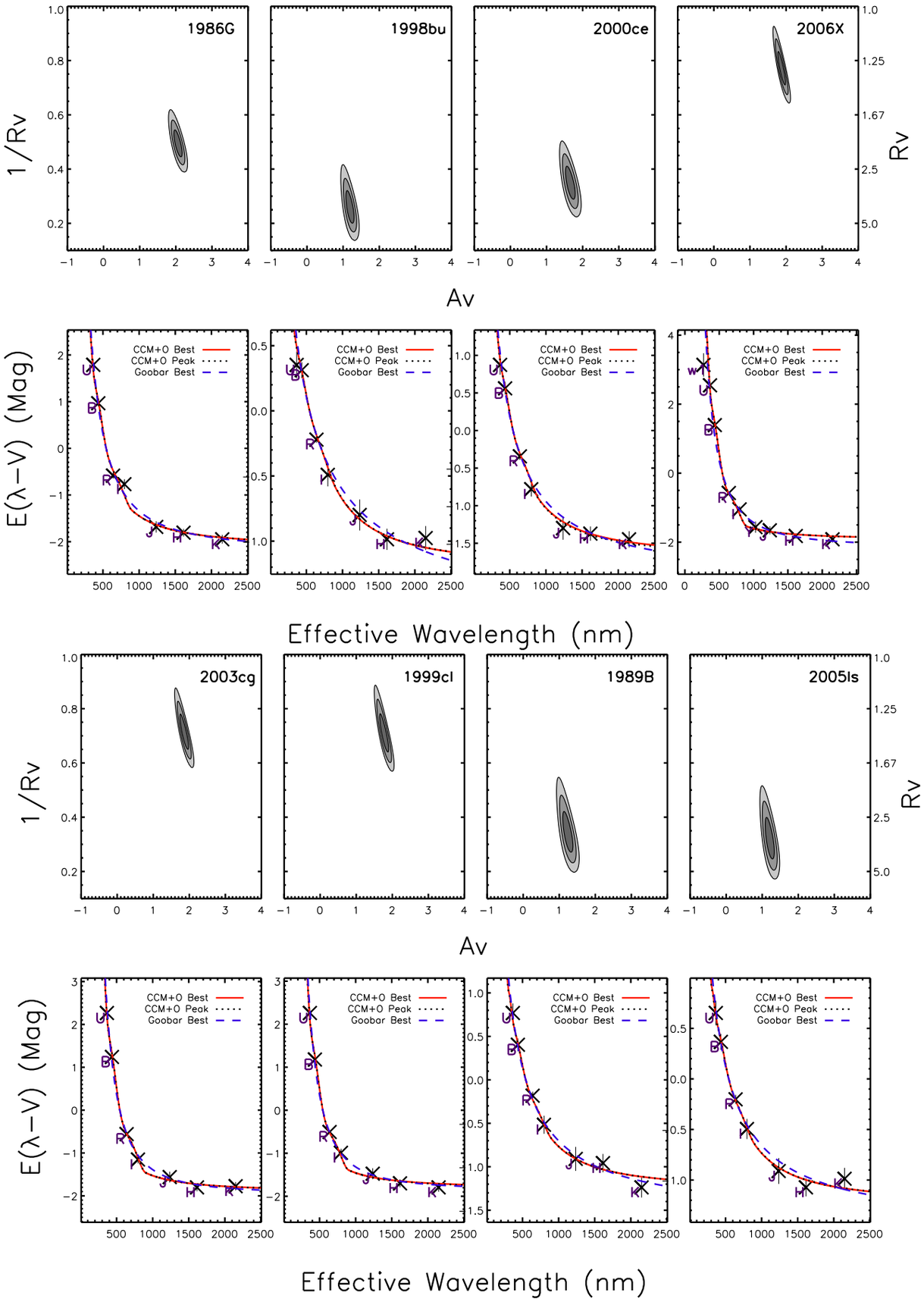
infrared data are very constraining

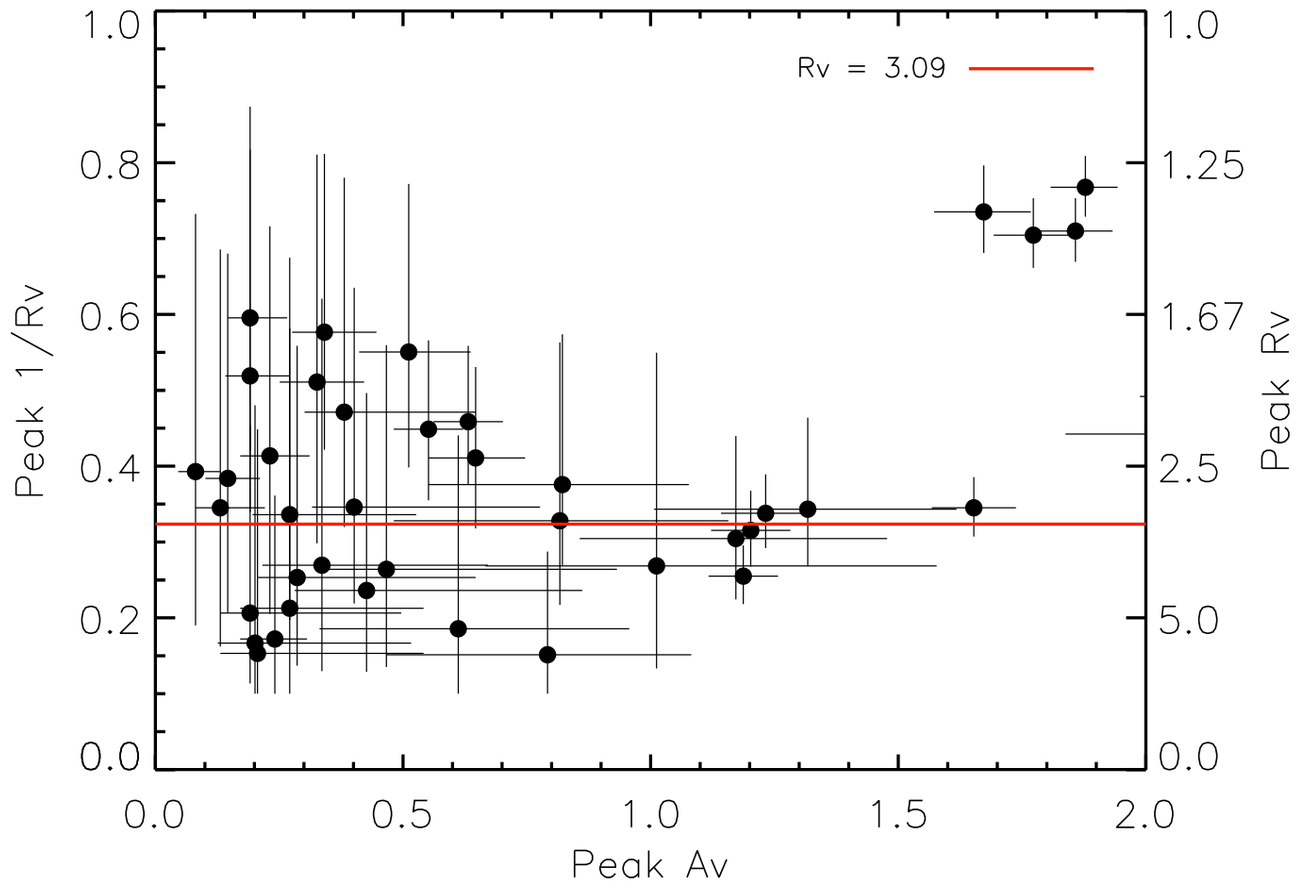
NUV to NIR SN Ia templates



Shappee & Jha (in prep)

extinction versus reddening





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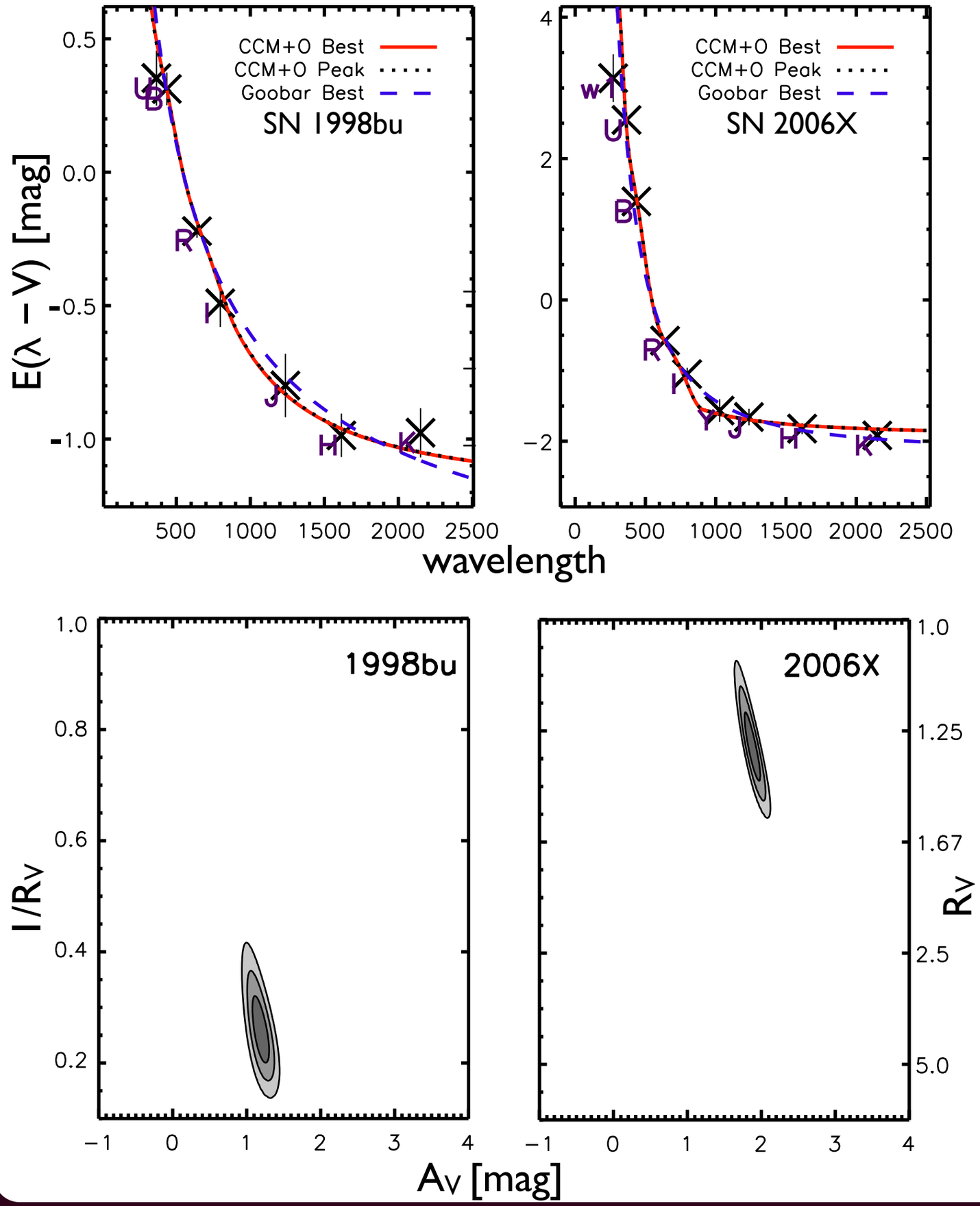

Shappee & Jha (in prep)

conclusions

- highly extinguished SN Ia have low R_V reddening and extinction
  - signature of "local" dust scattering?

- a few extinguished SN Ia have $R_V = 3.1$ reddening and extinction
  - some light echoes around these, dust screen >few hundred pc

- low-reddening SN Ia have low R_V extinction law, but normal reddening law
- indications of varying luminosity/color relationship vs. galaxy mass, sSFR (also different absolute magnitudes, but similar color distributions)
- hints? of varying luminosity/color relationship vs. SN Ia expansion velocity (could be different absolute magnitudes or different colors)
  - pointing to intrinsic color differences (at fixed light curve shape)

- quick(?) to do: really study color variation with phase